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5. RADIOMETRIC DATING AND TUFF MINERALOGY OF OMO GROUP DEPOSITS

F. H. Brown and W. P. Nash

Introduction

Through the efforts of the Omo Research Expedition and the East Rudolf Research Group, a large number of vertebrate fossils have been collected from the sedimentary deposits near the northern end of Lake Rudolf in Kenya and in the lower Omo valley in Ethiopia. The hominid fossils collected in this area have attracted the most attention, but the associated mammalian fossils are of equal importance, since they provide clues to the environment in which early man lived. Because these large collections of well-preserved material are extremely useful for correlation and for ascribing ages to other deposits, dating them is critical. In this chapter we try to describe some of the problems encountered in dating the deposits in the lower Omo valley, to assess some of the possible problems, and where possible to apply other controls to the radiometric dates. The work is not yet finished, and it may be many years before the final words are written on the age of these deposits. The following text is merely a summary of our knowledge to date.

Mineral Analyses

The stratigraphy and nomenclature of the sediments of the lower Omo valley have been discussed by de Heinzelin, Brown, and Howell (1970). A number of tuffs in the Shungura Formation have proved useful for obtaining radiometric dates and for dividing the formation into members. For a review of the nomenclature and stratigraphic position of these tuffs, see de Heinzelin, Brown and Howell (1970) and figure 6 of this paper.

We prepared samples of feldspar separated from the Omo Tuffs for electron microprobe analysis in order to determine the compositional variation within each sample and thus assess the possible effect of error in the potassium analyses on the ages of the samples.

The standard used for microprobe analysis potassium and sodium potassium was anorthoclase 5748, which is similar in composition to all of the samples analyzed (K_2O = 5.92%; Na_2O = 7.46%). The standard used for calcium was Crystal Bay bytownite (15.5% Ca). Barium and iron were analyzed using a synthetic barium silicate glass (46% BaO) and olivine YS-24 (11.54% FeO) respectively.

Data are presented in the form of histograms (fig. 1) and in tabular form where flame photometer analyses may be compared with the microprobe means. One hundred points approximately 10μ in diameter were taken on each sample, and the analyses were checked by converting the oxide percentages of Na_2O, K_2O, and CaO to albite, orthoclase, and anorthite,

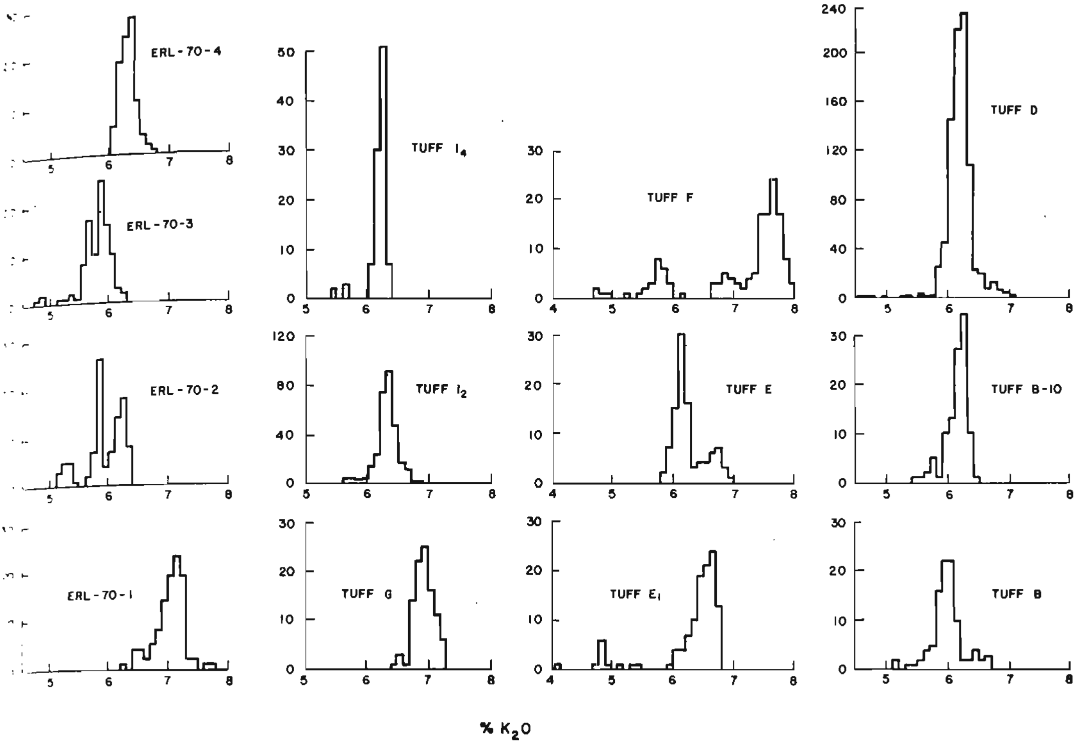

Figure 1. Histograms of potassium content of feldspars from various tuffs. The tuffs were grouped in 0.1 % intervals. On each plot the abscissa represents K_2O content and the ordinate represents the number of samples.

respectively. Since the barium component is small (less than 0.1% celsian), the sum of the feldspar molecules should be near 100%. Accordingly only analyses whose totals were between 98.5 and 101.0% were used in the plots and in calculating the means. For assessing the variation in Fe and Ba, only 50 points were analyzed.

In addition to the feldspars from the Omo tuffs, feldspars from tuffs from East Rudolf were analyzed, and the results of these determinations are presented in table 1 and figure 1 along with the Shungura results. The microprobe analyses of a number of samples of Tuff D are presented separately in table 2. Because of the similarity in age and composition of the feldspar, we suspected that Tuff D and the Tool Site Tuff at Koobi Fora (KF-2A;ERL-70-4) represented the same volcanic event. On the basis of potassium, sodium, and calcium contents, there is no way to distinguish the two feldspars, but the barium and iron contents may be used to establish that the two are distinct. In figure 2 the barium content of feldspars from the Tool Site Tuff is plotted against the iron content; a similar plot was made for the feldspars from Tuff D. On this diagram, it can be seen that although there is a small area of overlap, the two are distinguishable, the feldspar from the Tool Site Tuff having in general less iron and more barium than feldspars from Tuff D of the Shungura Formation.

In fact, the diagram in figure 3 shows that plotting barium content against iron content may be useful in distinguishing feldspars from various tuffs, since each of the four tuffs examined from East Rudolf has a distinct field when plotted on such a diagram. This is not true for the Omo tuffs, however, in which the feldspars from various tuffs plot in

Table 1

Analyses and Calculated Molecules of Feldspars from Various Tuffs

	B	B10	D*	E_i	E	F	G	I_2	I_4	L	KF-2	ERL-70-1	ERL-70-2	ERL-70-3	ERL-70-4	S1	S2	S5	S6
K_2O	6.03	6.10	6.19	6.36	6.26	6.61	6.96	6.32	6.18	5.91	6.22	7.01	5.92	5.67	6.27	7.21	6.39	6.40	6.56
Na_2O	7.50	7.56	7.47	7.17	7.37	7.07	6.88	7.37	7.45	7.39	7.48	6.90	7.67	7.78	7.43	6.76	7.33	7.36	7.26
CaO	0.17	0.15	0.06	0.14	0.08	0.13	0.03	0.07	0.10	0.38	0.10	0.01	0.02	0.13	0.08	0.01	0.01	0.07	0.01
BaO	0.01	0.06	0.01	0.08	0.01	0.03	0.01	0.03	0.04	0.19	0.04	0.01	0.16	0.30	0.04	0.03	0.01	0.04	0.03
Fe_2O_3	0.34	0.69	0.68	0.64	0.61	0.78	0.64	0.47	0.69	0.52	0.43	2.00	0.62	0.34	0.42	1.05	1.27	0.49	1.52
Calculated feldspar molecules (percentage by weight)																			
Or	35.63	36.05	36.58	37.61	37.00	39.07	41.13	37.35	36.52	34.91	36.76	41.42	34.99	33.51	37.06	42.63	37.78	37.81	38.76
Ab	63.47	63.98	63.21	60.67	62.36	59.83	58.21	62.38	63.04	62.49	63.30	58.38	64.90	65.83	62.87	57.23	62.00	62.24	61.45
An	0.84	0.74	0.30	0.69	0.40	0.64	0.15	0.35	0.50	1.88	0.50	1.05	0.10	0.64	0.40	0.05	0.05	0.33	0.05
Cs	0.02	0.15	0.02	0.20	0.02	0.07	0.02	0.07	0.09	0.47	0.10	0.02	0.39	0.73	0.10	0.08	0.03	0.11	0.08
Total	99.96	100.92	100.11	99.17	99.78	99.61	99.51	100.13	100.15	99.75	100.66	99.87	100.38	100.71	100.43	99.99	99.86	100.49	100.34
Electron microprobe and flame photometer K^+ values																			
Probe	5.01	5.06	5.14	5.30	5.20	5.49	5.78	5.25	5.13	4.91									
F. P.	4.659	5.074	5.097	5.080	5.186	6.101	5.912	5.124	5.095	3.35									
	4.964	5.054	--	--	--	6.233	5.886	5.182	5.010	3.13									
	--	--	--	--	--	--	--	5.111	4.99	--									

*Average value for Tuff D.

Table 2

Analyses and Calculated Molecules of Feldspar Separates from Tuff D

	F142	Tuff D	Tuff D	F160	UD-2	UD-3	208-12	LD-1	14D
K_2O	6.20	6.21	6.17	6.11	6.16	6.04	6.24	6.37	6.18
Na_2O	7.52	7.46	7.45	7.54	7.44	7.55	7.42	7.34	7.53
CaO	0.02	0.03	0.09	0.05	0.05	0.08	0.08	0.11	0.05
BaO	n.d.	n.d.	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Fe_2O_3	0.73	0.72	0.58	0.71	0.71	0.58	0.71	0.64	0.64
Calculated feldspar molecules (percentage by weight)									
Or	36.66	36.70	36.49	36.12	36.41	35.70	36.89	37.62	36.52
Ab	63.67	63.09	63.03	63.76	62.92	63.89	62.79	62.08	63.72
An	0.10	0.14	0.43	0.26	0.23	0.40	0.41	0.53	0.25
Cs	--	--	0.05	0.01	0.03	0.01	0.01	0.03	0.01
Total	100.43	99.93	100.00	100.15	99.59	100.00	100.10	100.26	100.50
Electron microprobe and flame photometer K^+ values									
Probe	5.15	5.15	5.12	5.07	5.11	5.01	5.18	5.29	5.13
F. P.	--	--	5.03	--	5.182	4.984	5.139	--	5.151

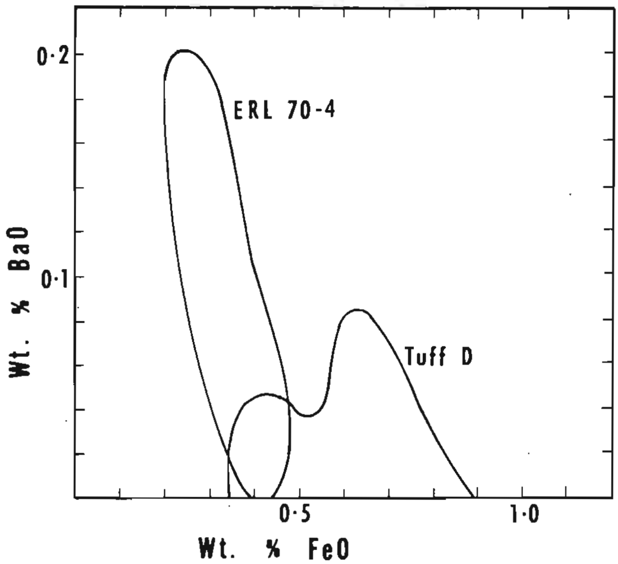

Figure 2. Barium content of feldspars separated from ERL-70-4 (KBS tuff) and Tuff D of the Shungura Formation plotted against iron content of the same.

the same general field. Such data might be useful if a tuff occurs where the stratigraphic situation is not well known, allowing one to eliminate some of the possible correlations.

The only possible correlation noted between the Omo tuffs and those of East Rudolf is between KNW2 and the specimen labeled ERL-70-3 from the Ileret area (Chari Tuff). Such a correlation gains support from the data presented in figures 4 and 5 and tables 1 and 3. In figure 4 the barium content of both feldspars is plotted against the iron content. The two sets of data are not separable on such a plot, nor are they separable in figure 5, where the iron content of the feldspar is plotted against the potassium content. In addition, the only mafic mineral noted in these two tuffs was a pyroxene; partial analyses of pyroxenes from each tuff are given in table 3, where it can be seen that the composition is strikingly

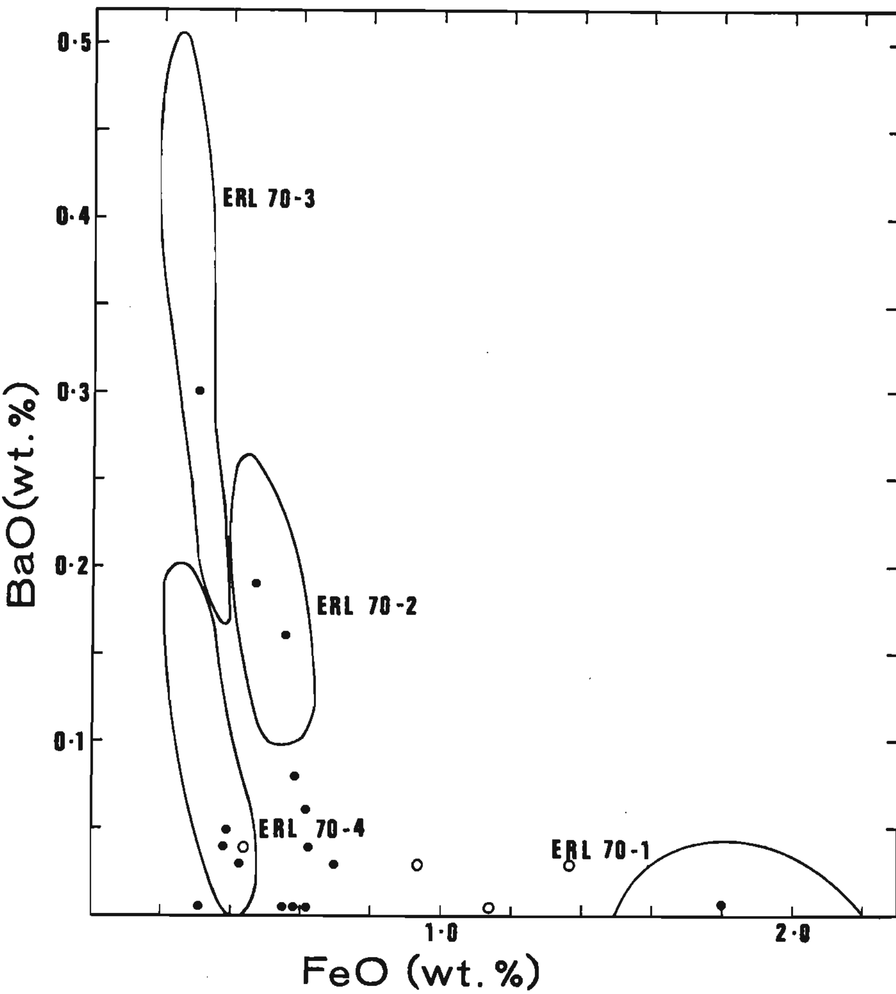

Figure 3. Barium content plotted against iron content of feldspars from various tuffs from East Rudolf. (See Appendix for sample locations.) *Open circles*, average values from Mount Damota feldspars; *closed circles*, average values from Shungura Formation tuffs.

similar. If individual pyroxene analyses are plotted in the pyroxene quadrilateral (diopside-hedenbergite-enstatite-ferrosilite), the trends of the two are again indistinguishable. This is not surprising, since most of the pyroxenes from the Omo and East Rudolf tuffs plot along the same trend, and the feature is not generally diagnostic. Some tuffs can be distinguished on such a diagram, however, and the method should not be overlooked.

Still another common feature between KNW2 and ERL-70-3 is the feldspar trend on the ternary feldspar diagram. Here again, the two prove indistinguishable, although the range in composition observed for KNW2 is somewhat larger than that for ERL-70-3. This greater range in composition probably accounts for the poor agreement between flame photometer values and the microprobe analyses for potassium (table 1), since a correspondingly larger number of data points is needed to define the mean over a larger range of composition. The

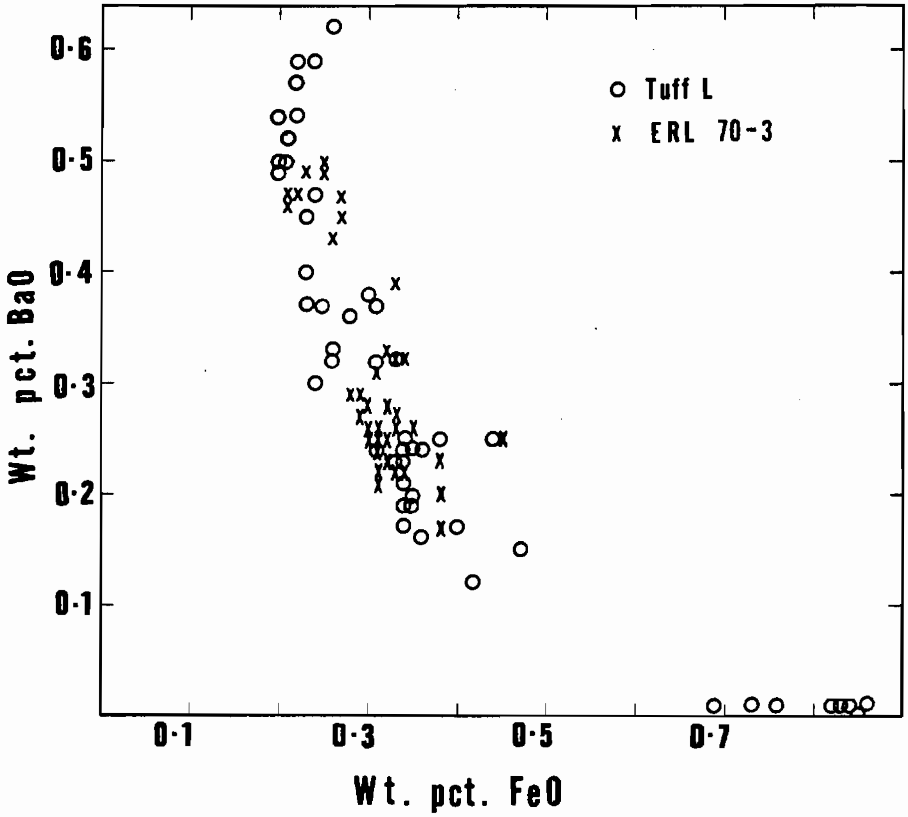

Figure 4. Barium content plotted against iron content of feldspars from Tuff L and ERL-70-3. (See Appendix for location of East Rudolf samples.)

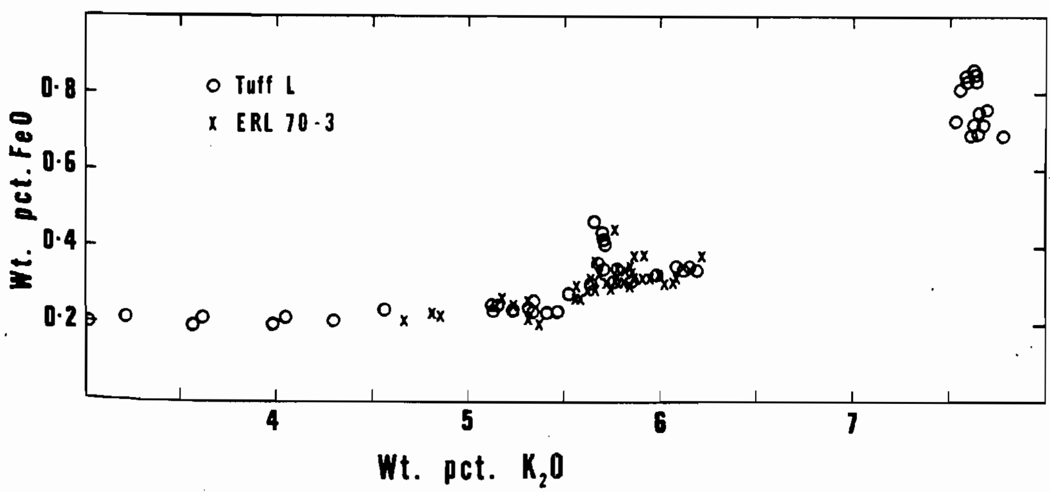

Figure 5. Iron content plotted against potassium content of feldspars from Tuff L and ERL-70-3. (See Appendix for location of East Rudolf samples.)

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Table 3

Pyroxene Analyses

	L	ERL-70-3	S1
SiO_2	--	--	48.6
TiO_2	0.3	0.3	0.33
Al_2O_3	0.4	0.3	0.23
FeO	23.7	25.6	29.0
MnO	1.65	1.68	2.68
MgO	4.6	3.1	0.89
CaO	19.0	19.3	17.4
Na_2O	0.6	0.6	1.30
Total			100.43

analyses of feldspars from other East Rudolf tuffs fall into other areas of the ternary feldspar diagram and appear to be diagnostic for each tuff.

All the evidence given in the preceding paragraphs is permissive only. That is, a correlation between KNW2 and ERL-70-3 cannot be ruled out; nor can a correlation be considered proved. The real tests lie in comparing the major and trace element contents of the two glasses as well as their radiometric ages and associated fauna. Should the correlation prove to be real, it will provide a welcome tie between the two sequences on direct stratigraphic grounds, even though the correlation is near the top of both sedimentary sequences.

Potassium-Argon Dates

The potassium-argon dates which have been run on samples from the lower Omo Valley are presented in table 4. Some of these dates have been published previously (Brown and Lajoie 1971; Brown 1972). A number of additional ones are included, and one date has been deleted from earlier lists (KA-2176), for reasons discussed below.

Potassium-argon ages have been obtained for three new stratigraphic horizons in the Shungura Formation. For stratigraphic details on previously published dates see de Heinzelin, Brown, and Howell 1970; only the newly dated stratigraphic levels are discussed below.

Tuff B-10 is a minor tuff about 20 cm thick which is locally preserved at the base of submember 10 in Member B of the Shungura Formation. The only known outcrops of this tuff are at Locality 1. The glass in this tuff is completely altered to clay, but remnants of the structure can be seen. Large crystals of anorthoclase (to 4 mm) occur. We separated these and made two determinations of the argon and potassium contents on splits of the purified feldspar. The resulting dates are in good agreement (2.93 and 2.96 m.y.) and yield an average age of 2.95 $\pm$ 0.1 m.y.

The dates on samples KNW2 are on anorthoclase from a tuff collected near the top of the section, in the western exposures. The approximate position of this tuff with respect to Tuff G is shown in the schematic diagram in figure 6. We approximated this stratigraphic position by calculating from the outcrop width on the map, and it may be in considerable error. The potassium analyses are in good agreement, but the argon determinations vary by

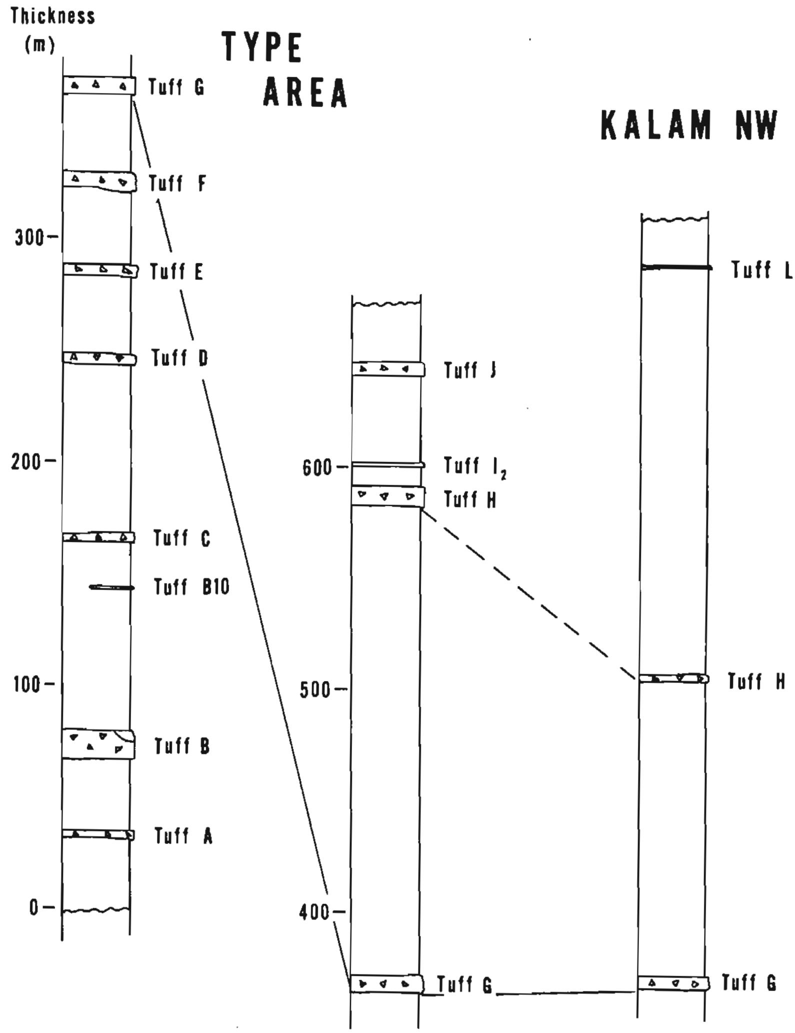

Figure 6. Schematic diagram of the stratigraphy of the Shungura Formation in the type area and in the exposures northwest of Kalam.

about 10%, leading to the rather large difference in the two ages (1.27; 1.41 m.y.). The average of these is 1.34 m.y., and we prefer to use this average rather than argue the merits of one age or the other. The most immediate use of this date is to roughly define the upper time limit on the Shungura Formation as something less than about 1.34 ± 0.15 m.y.

During reconnaissance mapping a hominid molar was found in the Kalam West exposures, and approximately 15 m below this in the section a pumiceous tuff was found and dated. The hominid molar thus appears to be only about 1.4 m.y. old, and therefore much younger than most of the hominid material from the Shungura Formation.

We also found a rich fossil locality near Namaruputh, and the date for a tuff stratigraphically within a few meters of the fossil horizon yielded an age of 1.51 ± 0.1 m.y. The fauna of F8 is of roughly this age also, and helps to place it stratigraphically, as no

Table 4

Potassium-Argon Ages and Related Data

	Horizon	Lab. No.	Wt.(gm)	K^+(%)	Ar^{40}_{atm} (%)	Ar^{40}_{rad} ($x10^{-11}$ moles)	Ar^{40}_{rad}/gm ($x10^{-11}$ moles)	K^{40}/gm ($x10^{-8}$ moles)	Calculated Age ($x10^6$ years)
SHUNGURA FORMATION	Tuff L	KA-2504	3.35558	4.510	71.2	3.4075	1.0155	13.72	1.27 ± 0.10
	Tuff L	KA-2505	3.13131	4.490	72.9	3.5283	1.1268	13.66	1.41 ± 0.10
	F223	KA-2521	3.01333	4.140	79.0	3.1771	1.0543	12.59	1.43 ± 0.10
	KAR OLO	KA-2516	3.33791	4.246	71.1	3.7980	1.1380	12.92	1.51 ± 0.10
	Tuff I_2	KA-2509	3.0537	5.124	24.5	5.032	1.648	15.59	1.81 ± 0.09
	Tuff I_2	KA-2187	5.2886	5.182	54.8	8.824	1.668	15.77	1.81 ± 0.09
	Tuff I_2	KA-2085	5.0010	5.111	--	--	--	15.55	1.87 ± 0.09
	Tuff G	LKA-9	1.9868	5.899	59.3	4.0173	2.022	17.95	1.93 ± 0.10
	Tuff F	LKA-11	1.6682	6.101	66.4	3.597	2.156	18.56	1.99 ± 0.10
	Tuff F	LKA-21	2.0586	6.101	48.2	4.595	2.232	18.56	2.06 ± 0.10
	Tuff E_i	LKA-14	2.3350	5.010	49.1	4.4136	1.890	15.24	2.12 ± 0.11
	Tuff D	KA-2519	2.93381	5.139	44.0	5.795	1.975	15.64	2.16 ± 0.11
	Tuff D	LKA-23	1.80134	5.151	52.4	3.557	1.975	15.67	2.16 ± 0.11
	Tuff D	LKA-22	1.64782	5.151	37.3	3.490	2.118	15.67	2.31 ± 0.11
	Tuff D	KA-2510R	2.99531	4.984	46.7	6.411	2.141	15.16	2.41 ± 0.12
	Tuff D	KA-2511	3.06549	5.182	30.9	7.084	2.311	15.77	2.51 ± 0.12
	Tuff D	KA-2067	5.00225	5.151	51.0	11.70	2.340	15.67	2.56 ± 0.12
	Tuff D	ℓ1040	1.6675	5.030	34.0	3.882	2.328	15.31	2.60 ± 0.12
	Tuff B10	KA-2458	3.10180	5.002	35.7	8.0881	2.608	15.22	2.93 ± 0.10
	Tuff B10	KA-2441	3.04414	5.064	60.0	8.1045	2.674	15.41	2.96 ± 0.10
	Tuff B	KA-2096	6.0050	4.625	50.3	18.74	3.120	14.07	3.79 ± 0.20
	Tuff B	ℓ1029	1.2379	4.474	44.5	4.9259	3.9792	13.62	4.99 ± 0.2
USNO FORMATION	Triple Tuff	LKA-25	0.77656	2.830	91.6	1.0163	1.3087	8.61	2.64 ± 0.92
	Triple Tuff	ℓ1027	1.5878	2.640	89.8	2.292	1.4434	8.03	2.97 ± 0.3
	WS Basalt	KRL-2	10.8442	0.7074	84.5	4.2487	3.9179	2.152	3.11 ± 0.15
	WS Basalt	LKA-20	6.3263	0.7074	90.7	2.7958	4.419	2.152	3.51 ± 0.70
MURSI FORMATION	Yellow Sands Basalt	KA-2094	10.1667	0.828	75.4	6.067	0.5967	2.520	4.05 ± 0.2
	Nkalabong Basalt	KA-2508	1.81778	0.515	56.3	3.367	1.852	1.567	20.1 ± 2
	Nkalabong metamorphic	KA-2515	0.00516	10.969	43.8	5.1232	992.9	33.379	451 ± 20

direct connection has been found between the exposures southwest of Kalam and the type section to the north.

Brown (1969) originally published two dates for Tuff D (KA-2067 and KA-2176). While compiling the data for the table of dates which appears in this chapter, we noticed that the potassium content of KA-2176 was exceptionally high compared with the other samples. The published value was $K^+ = 5.432\%$ (= 6.544% K_2O). Since this is much higher than the mean value determined by microprobe, the value was checked from the original run sheets. It was found that the calculations were correct, and that since sodium had been run at the same time, the analysis could be checked for internal consistency. This was done by converting to feldspar molecules (see above) and summing. The resulting total was 95.63%; adding in the average anorthite and celsian contents brings the total to less than 96%. Clearly something is amiss, and the best procedure seems to be to delete the date from the list.

The remaining dates obtained on Tuff D are presented in order of age in table 4. One can immediately see that the relation between potassium content and age is obscure, but that the variation of age with argon content is nearly linear. This strongly suggests that the variation in the measured ages results from a variation in argon content. In any case, the spread in ages cannot be attributed solely to potassium error. For example, the potassium content of KA-2519 and LKA-23 would have to be only 5.57% K_2O if the age is to be brought up to the mean (2.4 m.y.). A glance at figure 1 will convince the reader that a potassium content this low is unlikely for any sample of Tuff D.

If the potassium determinations are not the source of error, then the problem must lie in the argon determinations or the argon content. Similar values of argon content for feldspars from Tuff D have been reported from Lamont and Berkeley (LKA-23 and KA-2519), and also from the United States Geological Survey at Menlo Park and Berkeley (compare ℓ1040 and KA-2067). This leads to the suspicion that the determinations are not in error, leaving one with the conclusion that the argon content is variable.

The question then arises whether from a geochronological point of view the low values or the high ones are in error. High argon values could be caused by extraneous argon from a number of sources; low values might result from leakage.

In 1971 we found that there were two distinct levels of pumice in Tuff D, and it was suggested that perhaps part of the reason for the large spread in ages was that pumice had been collected from these different levels. The feldspar from both levels is of the same composition, and this may be taken as evidence that the tuff represents a single volcanic event. It may also be argued that the two levels represent two separate volcanic events but that the feldspar happens to be of the same composition. In any case the dates KA-2510R and KA-2511 fall into the older category rather than into the young set, and both are from the upper pumice level. De Heinzelin (pers. comm.) has suggested that the pumices of the lower level were exposed to some grade of incipient weathering, with possible consequent loss of argon, whereas those of the upper pumice level "look indeed fresher, and are expected to be more reliable."

A second date (4.99 m.y.) has now been determined for Tuff B (see table 4), which is in marked disagreement with the earlier date (3.79 m.y.). The data on both dates have been reexamined, and there seems to be no reason to doubt either of the argon determinations or the potassium determinations. The possibility of contamination by older feldspar is much greater for Tuff B than for any of the other tuffs, and although care was taken to avoid this, the pumice clasts from Tuff B are small and contamination cannot be considered impossible. Paleomagnetic data indicate that both dates may be in error.

A second date has also been obtained on the thick tuff underlying the fossiliferous deposits of the Usno Formation. This date is considered more reliable than the earlier date, and it is likely that the age of the fossils from this formation are slightly older than the previous estimate given by Brown (1972). At that time, the only date available was 2.64 ± 0.92 m.y., and the fossils were supposed to be approximately 90,000 years younger than this. Assuming that the newer date is more nearly correct, the fossils at White Sands and Brown Sands should be about 2.9 m.y. in age.

Two other dates of interest are those of KA-2515 and KA-2508. Of the three groups of rocks exposed in the Nkalabong range, the oldest is the crystalline basement; its outcrops restricted to the lower reaches of a narrow canyon which lies almost due southeast of the peak of the range and debouches onto the plain of the northern lower Omo basin. The rocks consist of folded gneisses which have been subsequently cut by pegmatites and aplites made up dominantly of alkali feldspars, quartz, and accessory muscovite. A sample of orthoclase from one of the pegmatites yielded an age of 451 ± 20 m.y. It must be emphasized that this date represents a minimum estimate because the specimen records the latest event recognizable in the metamorphic complex and because the feldspar is perthitized. Perthitized feldspars are known to give low ages relative to biotite from the same rock; typically the ages are 20 to 30% too low, but they may be as much as 85% too low (see Dalrymple and Lanphere 1969, p. 168).

Overlying the crystalline basement is a group of lavas and pyroclastic rocks which make up the bulk of the mountain. The lavas consist dominantly of fine-grained basalt and porphyritic rhyolites and trachytes. Basaltic flows here seldom exceed 12 to 15 m in thickness and are often less than 6 m thick. In contrast, the rhyolites are rather thick, single flows often exceeding 60 m. The total thickness of this volcanic sequence is probably greater than 1,500 m. The oldest flows rest directly on the metamorphic complex and are basaltic. Feeder dikes which cut the metamorphic rocks are well exposed in the canyon mentioned above. It appears that the succession consists of basalts overlain by rhyolites and trachytes, followed again by a sequence of basalt, and finally rhyolite. Near the top of the range, a thick tuff breccia occurs overlain by a sodic rhyolite.

The southwestern portion of Nkalabong is made up of massive rhyolites and rhyolitic tuffs. Silicified wood similar to that noted by Fuchs (1939) near Naramum in the Lorienatom range is common on these western slopes.

The overall petrographic and structural similarity leads one to suspect that the older volcanic sequence on Nkalabong might correlate with the Tertiary lavas of Lorienatom and Lokwanamur to the southwest. These lavas are mapped as Tertiary olivine basalts and rhyolites by Walsh and Dodson (1969), and Reilly et al. (1966) have obtained potassium-argon ages of 23 m.y. on the upper basalt sequence (Tvb_2) of Walsh and Dodson. We separated plagioclase from a porphyritic basalt found near the middle of the older volcanic sequence on Nkalabong and obtained a date of 20.1 ± 2 m.y. This lends credence to the supposed correlation between the two sets of volcanic rocks.

The third group of rocks on Nkalabong is a series of thin basalt flows exposed on the northwestern side of Nkalabong. The flows dip gently to the west and often exhibit columnar jointing. The basalts are nonporphyritic and consist of interlocking laths of medium plagioclase, clinopyroxene, and ilmenite in roughly equal-sized grains, with turbid altered glass filling the interstices. Olivine grains are occasionally seen, of hortonolitic to chrysolitic composition. Dikes cut the flows, but petrographically are exactly the same. The most distinctive feature of these lavas is their regularity in grain size and mineralogy. It is not possible to distinguish a lava from the top of the sequence from one at the bottom, nor is it possible to distinguish a dike from a flow by petrographic means.

The basalt which occurs at Yellow Sands is of this petrographic type, as is the basalt at the White Sands fossil locality. The dates of these basalts, 3.3 m.y. and 4.1 m.y., perhaps represent the latter part of the volcanism. Occasional lenses of tuff and coarse gravels occur intercalated with the lavas on the northern slopes of Nkalabong, and it is possible that these in some way correlate with the Yellow Sands sequence of sediments described by Butzer and Thurber (1969).

Possible Source Area of the Tuffs

Brown (1972) suggested that Mount Damota near Soddu in Ethiopia might be a likely source for at least some of the tuffs of the Shungura Formation. Petrography of a small collection of rocks from this mountain indicates that the lavas are silica-rich and peralkaline. All samples contain phenocrysts of quartz and anorthoclase. In addition they contain alkali amphibole, enigmatite, sodic hedenbergite, fayalite, and manganese-rich ilmenite. In all of these features, the Damota rocks are similar to the Shungura tuffs.

Average analyses of feldspars from the Damota rocks are given in table 1 (sample numbers S1 to S6), and an average pyroxene analysis is given in table 3. Average BaO and FeO contents of feldspars from Soddu are plotted in figure 3. In terms of CaO-Na_2O-K_2O contents, feldspars from Soddu lie on the compositional trend of those from the Omo tuffs and, with one exception, fall within the most common compositional variation limits of the tuff feldspars.

The amphiboles in the Soddu samples are richer in iron than those analyzed from the Omo tuffs. They are also richer in Ti and Na and depleted in Mg and Ca. Although basically similar, the Soddu amphiboles are more highly evolved in terms of magmatic differentiation. Similarly, the pyroxenes are generally more iron-rich than most of those from the Omo tuffs, although they do fall at the iron-rich end of the Omo CaO-MgO-FeO compositional variation trend.

The similarity in rock types and mineralogy of Shungura tuffs and the lavas from Mount Damota indicates that the latter is a possible source for the tuffs. As an example, feldspars from sample S5 strongly resemble feldspars from tuffs I_2, KF-2, and ERL-70-4. However, none of the Soddu samples can be positively correlated with a specific Shungura tuff at this time.

Summary and Conclusions

The sediments of the lower Omo basin span an age range from somewhat greater than 4 m.y. to somewhat less than 1.4 m.y, excluding the younger sedimentary accumulations (Bourillé and Kibish formations). Although most potassium-argon ages are supported by the paleomagnetic evidence collected so far, problems have been noted, and it is possible that some revisions in age estimates may become necessary as more work is done.

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Appendix: Locality Data for East Rudolf Tuffs

ERL 70-1	Pumice from lacustrine tuff, Koobi Fora area (Upper Member, Koobi Fora Tuff)
ERL 70-2	Pumice from lacustrine tuff, Sibilot area (Kubi Algi Formation, lower tuff)
ERL 70-3	Pumice from lacustrine tuff, Ileret area (Ileret Member, Chari Tuff)
ERL 70-4	Pumice from the "Tool Site Tuff," Koobi Fora area (KBS Tuff)
KF 2	Pumice from fluvial tuff, Koobi Fora area (Koobi Fora IIA) (KBS Tuff)

For an explanation of stratigraphic nomenclature and maps, see Vondra and Bowen, Findlater (this symposium).

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